PRUDENCE©
Approach & Lessons Learned

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http://prudence.dmi.dk

©Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects - Contract No. EVK2-2001-00156

Workshop on CEC Project for Intercomparison of Simulations of California's Climate
June 11, 2004 Sacramento, CA

1. **Danish Meteorological Institute, Copenhagen, DK**
2. CINECA, Bologna, IT
3. Météo-France/CNRM, Toulouse, FRA
4. Deutsches Zentrum für Luft- und Raumfahrt e.V., Weßling, GER
5. Hadley Centre for Climate Prediction and Research, Met Office, Bracknell, UK½
6. Climate Research ETH (Eidsgenössische Technische Hochschule), Zürich, CH
7. GKSS Research Center (Institute for Coastal Research), Geesthacht, GER
8. Max Planck Institut für Meteorologie, Hamburg, GER
9. Swedish Meteorological and Hydrological Institute, Rossby Centre, Norrköping, SWE
10. Universidad Complutense, Madrid, SP
11. Universidad Politecnica, Madrid, SP
12. International Centre for Theoretical Physics, Trieste, IT
13. Danish Institute of Agricultural Sciences, Foulum, DK
14. Risø National Laboratory, System Analysis Dept., DK
15. University of Fribourg, CH
16. Finnish Environmental Institute, Helsinki, FIN
17. University of Reading, UK
18. University of Lund, SWE
19. Centre International de Reserche sur l'Environment et Developpement,SMASH, Paris, FRA
20. Climate Research Unit, University of East Anglia, UK
21. Finnish Meteorological Institute, Associated to FEI (No. 16), FIN

A. Norwegian Meteorological Institute, Blindern, NO
B. Royal Dutch Meteorological Institute, De Bilt, NL
C. UQAM, Montreal, CAN
D. CSIRO, Victoria, AUS
E. Czech Republic, Israel, Greece, Belgium, Slovakia……..
F. Munich-Re, Electricité de France, Elforsk, Hamburg Institute of International Economics, Uni-Münster, DG-Research, **STARDEX, MICE**

Overview

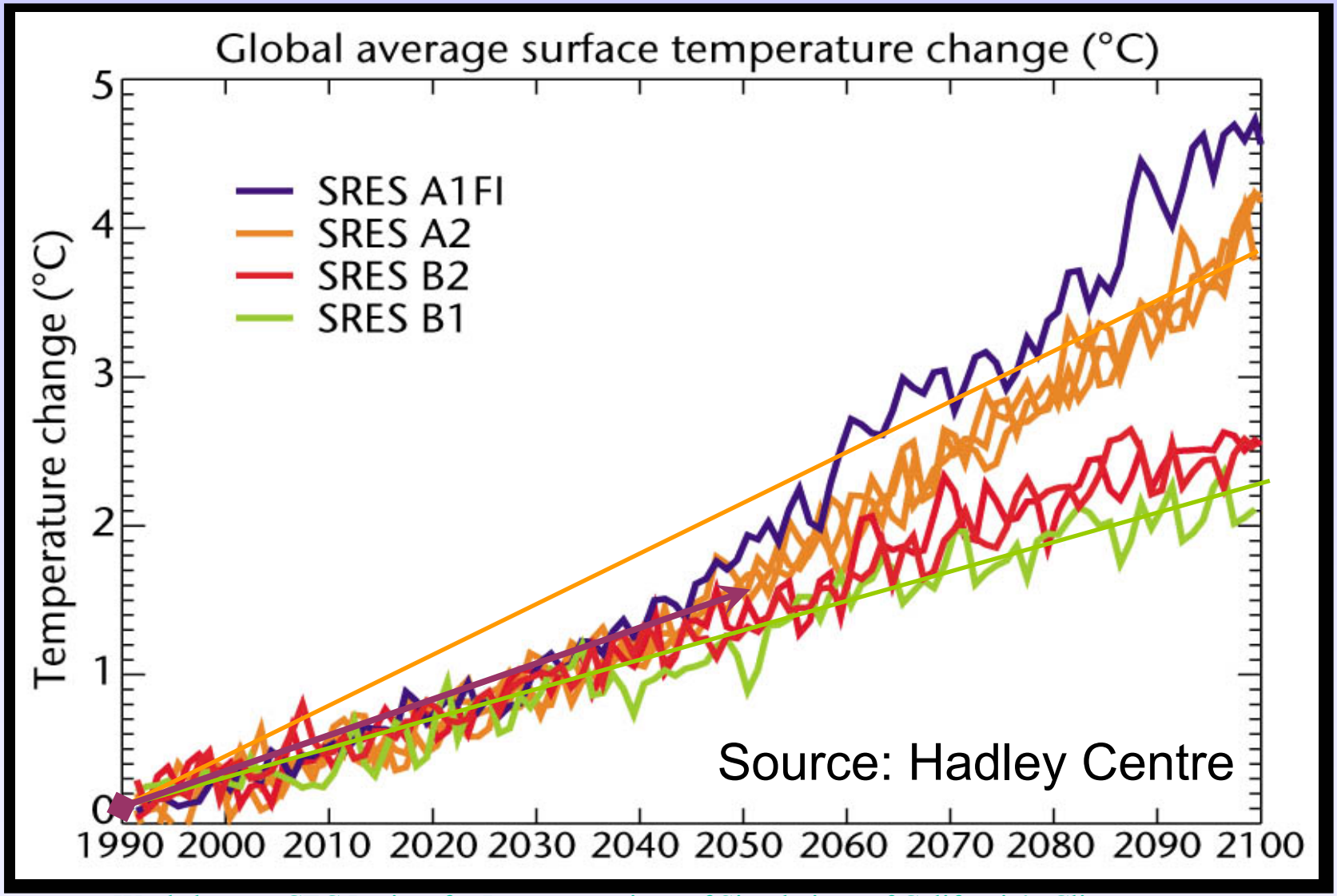
- Sources of uncertainties in climate change projections
  - The objective is to reduce and/or quantify them
- PRUDENCE – ultra brief
- Inter-model variability and intercomparison
  - Extremes as an example
- Reducing uncertainties
- Summary, outlook, and conclusions

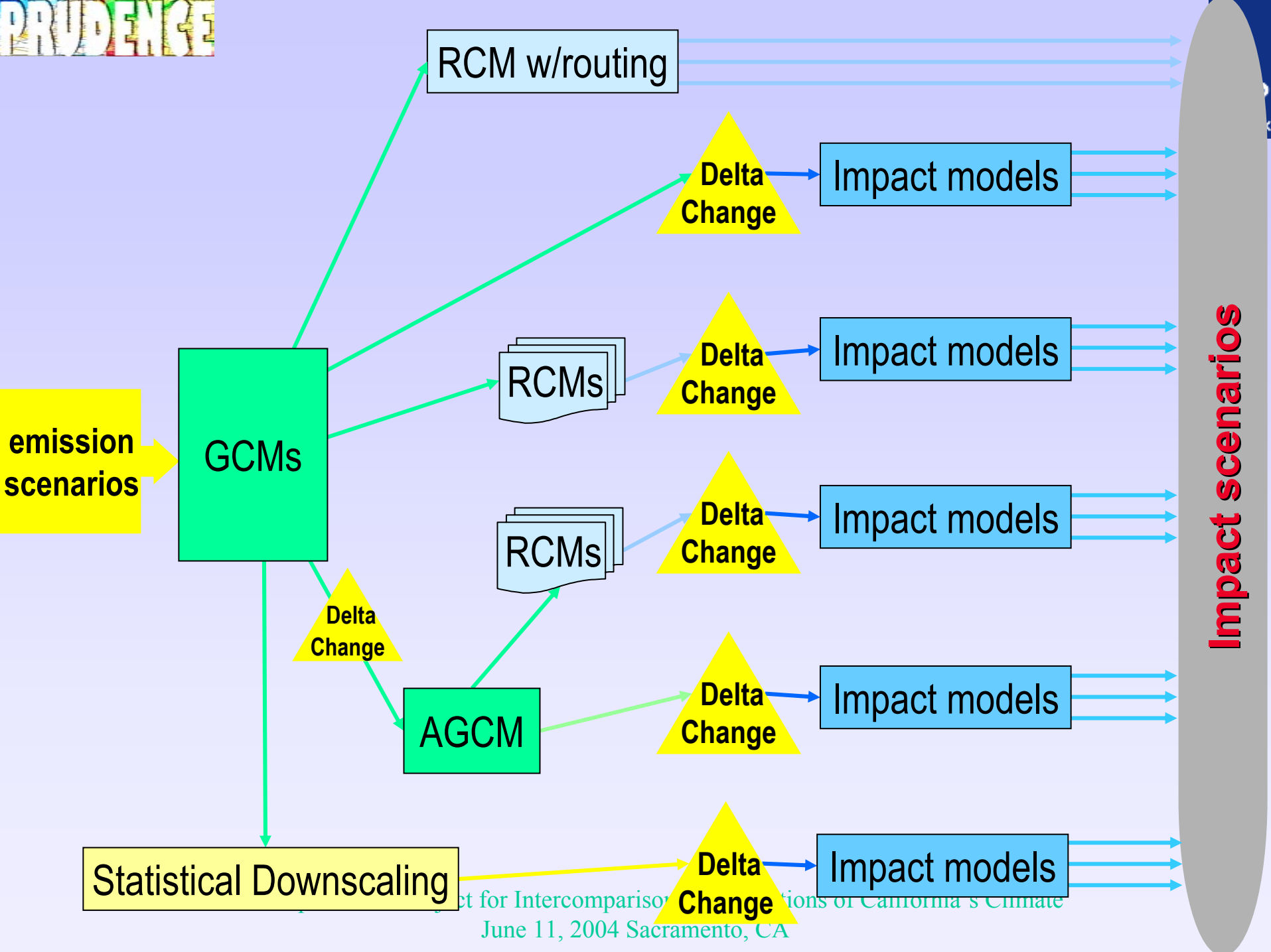
UNCERTAINTIES IN CLIMATE CHANGE PROJECTIONS

- **Uncertainty due to observational limitations**
  - use multiple means of validation
- **Uncertainty in future emissions**
  - use a range of SRES emissions scenarios
- **Natural variability (within models)**
  - use a number of different initial conditions
- **Uncertainty in the response of the climate system**
  - use a range of climate modelling systems including impact models
  - **AND/OR** assess confidence in climate change projections
- **Need for a large-scale coordinated effort**

GLOBAL TEMPERATURE RISE

due to four SRES emissions scenarios

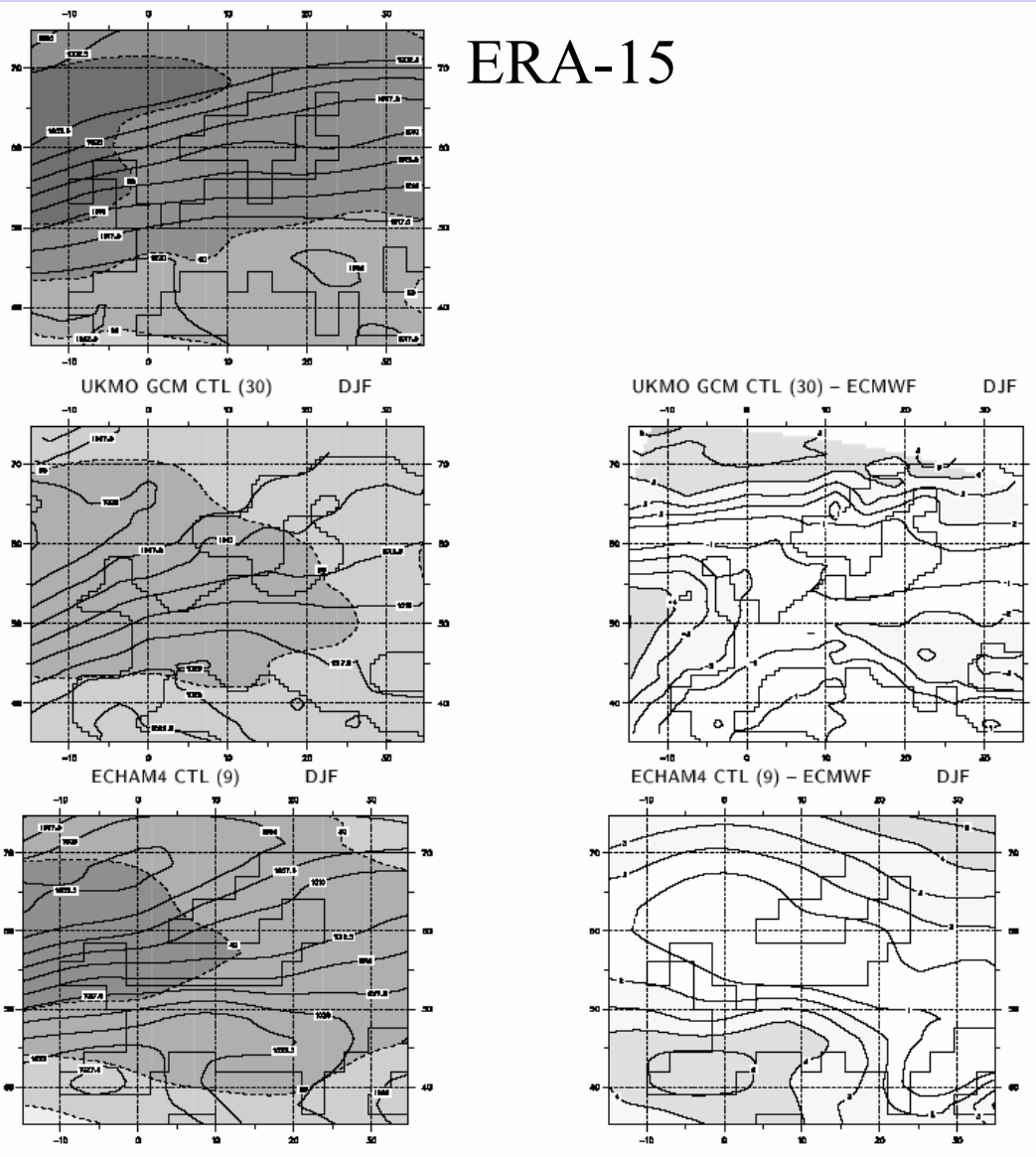



RCM w/routing
Delta Change
Impact models
RCMs
Delta Change
Impact models
emission scenarios
GCMs
RCMs
Delta Change
Impact models
Delta Change
AGCM
Delta Change
Impact models
Statistical Downscaling
Delta Change
Impact models
Impact scenarios

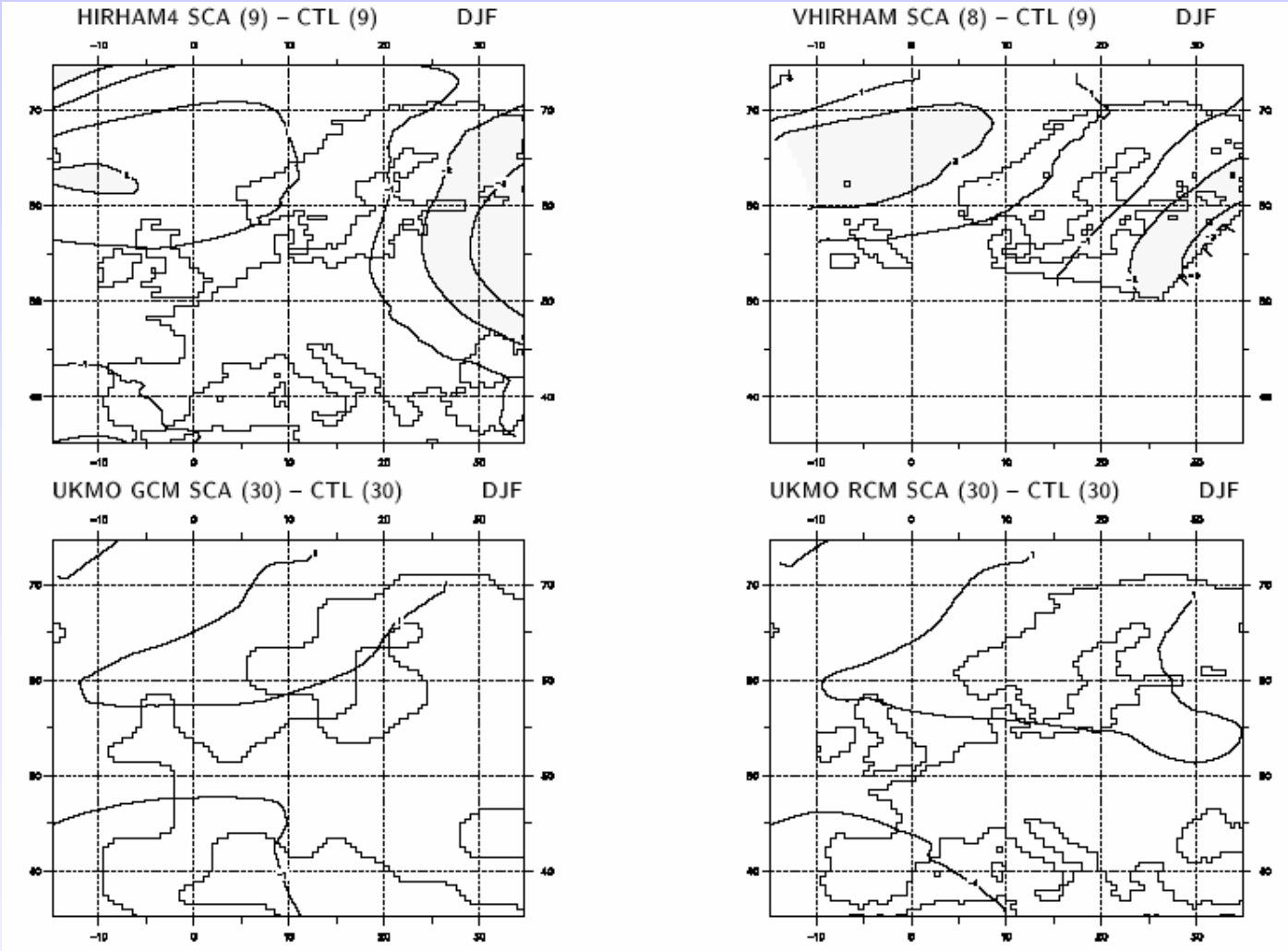
PRUDENCE: The project

- Climate modelling
- Impacts modelling and analysis
- Policy and dissemination

Uncertainty due to GCM: Present climate



Uncertainty due to GCM: Change

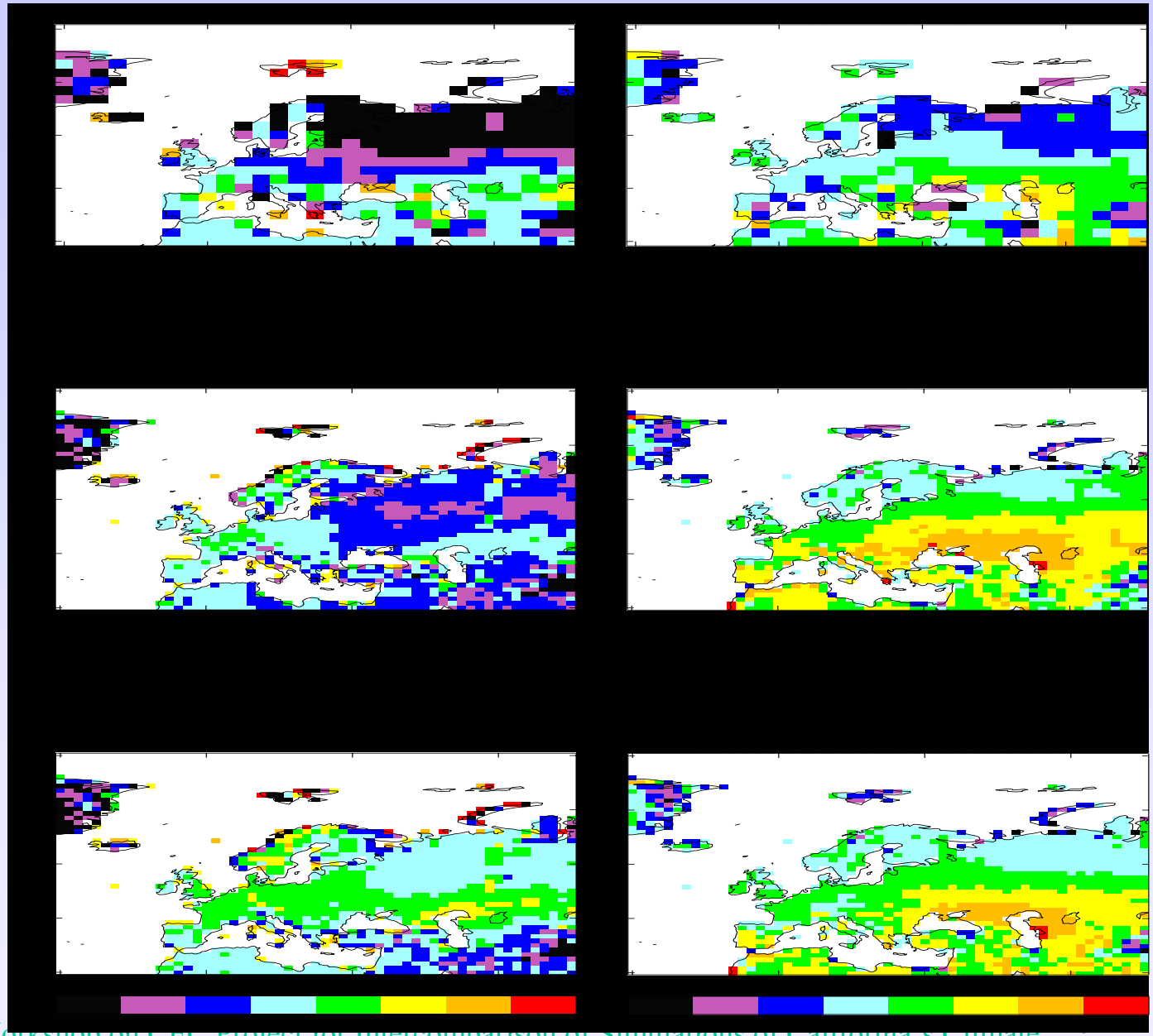


Bias in near surface air temperature

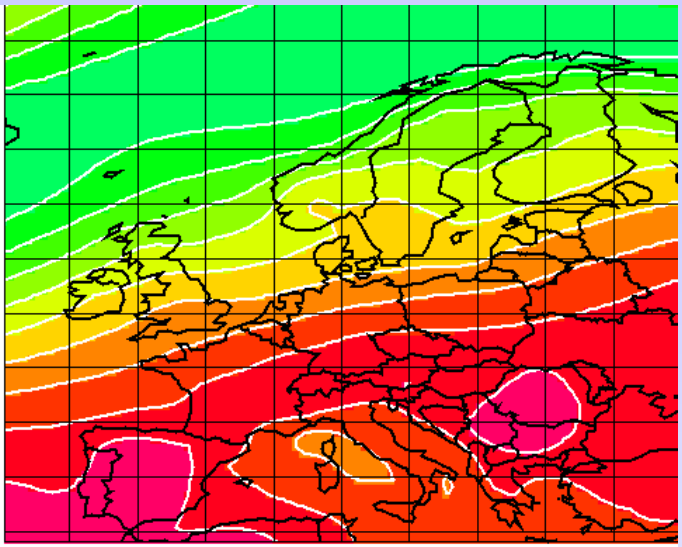
HadCM3
300km

HadAM3
150km

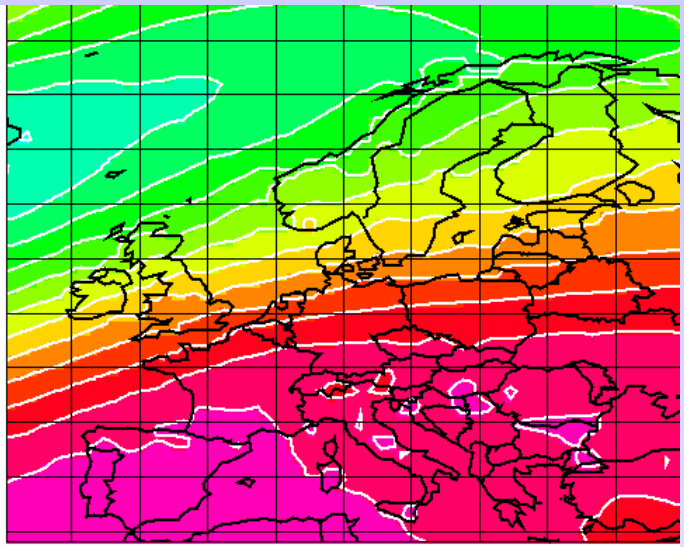
HadAM3
150km +
improved
physics



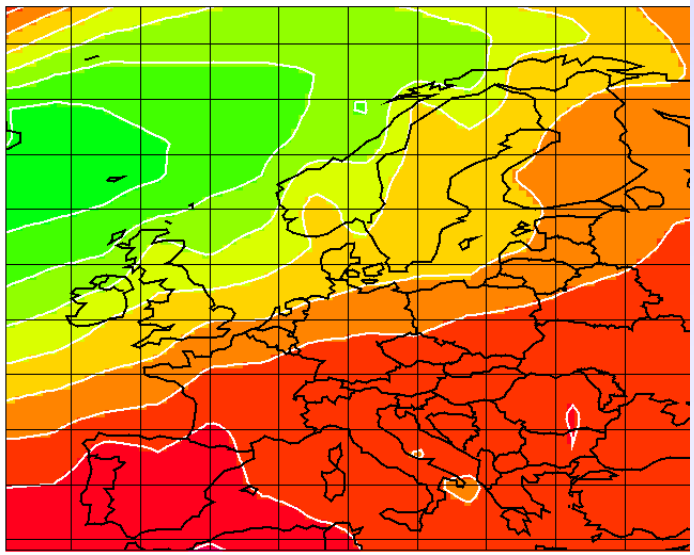
ERA-40



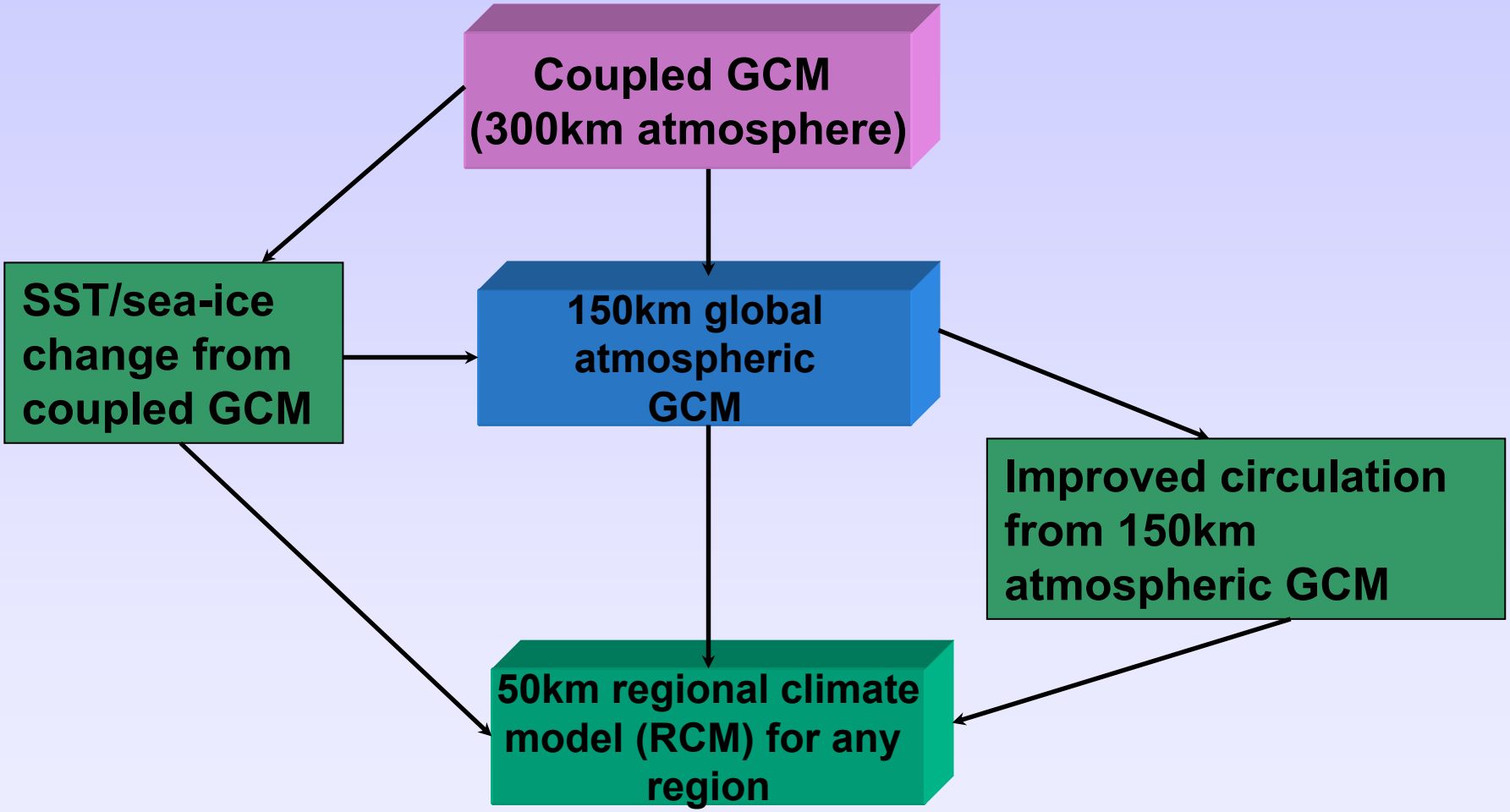
HadAM3H



HadCM3



A modelling system for detailed regional scenarios

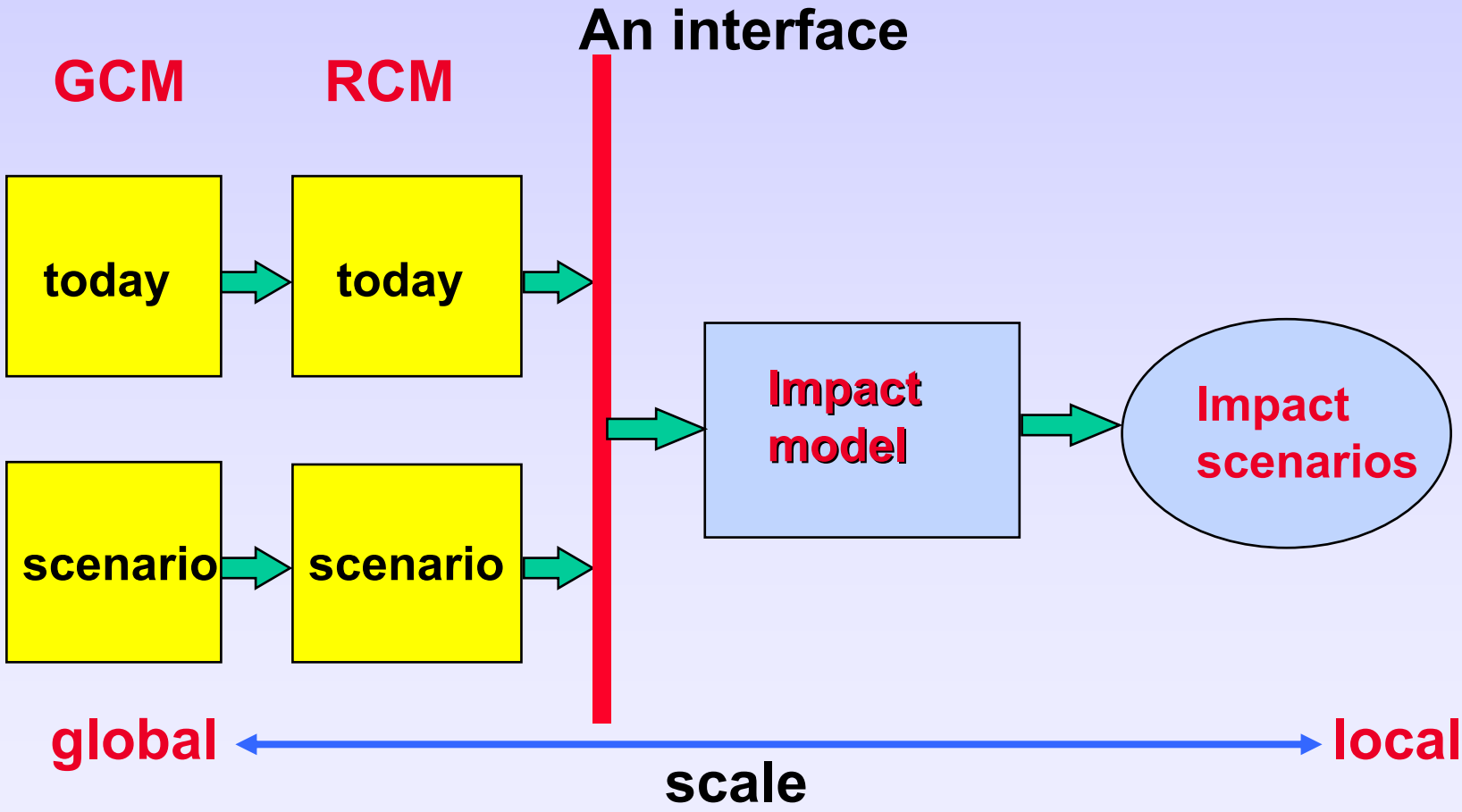


PRUDENCE protocol

- High resolution A-GCM using 1961-1990 observed SSTs
  - Better control climate than low resolution CGCM
- High resolution A-GCM using SST anomalies for 2070-2100 from transient CGCM experiment
  - Greenhouse gas concentrations and aerosols according to IPCC SRES scenarios (A2, B2)
- HadAM3H, HadAM3P (PRECIS), Arpege, ECHAM5, CCM3

A road to impact scenarios

a.k.a. the Delta Change approach



AGCM / **exp forcing**	HadAM3H	ARPEGE	ECHAM5	CCM3
HadCM3 SRES A2	3 ensemble members 150 km **BDY 1**	2 mem high res.	1 member T106	2 members T80 **BDY4** 100km
HadCM3 SRES B2	1 member 150 km **BDY 2**	1 mem high res.		
ECHAM4/OPYC3 SRES A2			1 member T106 **BDY 3** **T42**	
ARPEGE/OPA SRES B2	Meteo	1 mem high res.		

RCM 50km / **Input**	Had	Rossby	DMI	Es	ETH	IPCC	MPI	GKSS
BDY 1	3 mem		3 mem					
BDY 1		1 mem		1 mem	1 mem	1 mem	1 mem	1 mem
BDY 1 ini cond.							1 mem	
BDY 2	1 mem	1 mem		1 mem				
BDY 3			1 mem					
BDY 4						1 mem		

RCM 20 km / **Input**	P5	P9	P1		P6		P8	
BDY 1	1 mem	1 mem	1 mem		1 mem		1 mem	

12 km

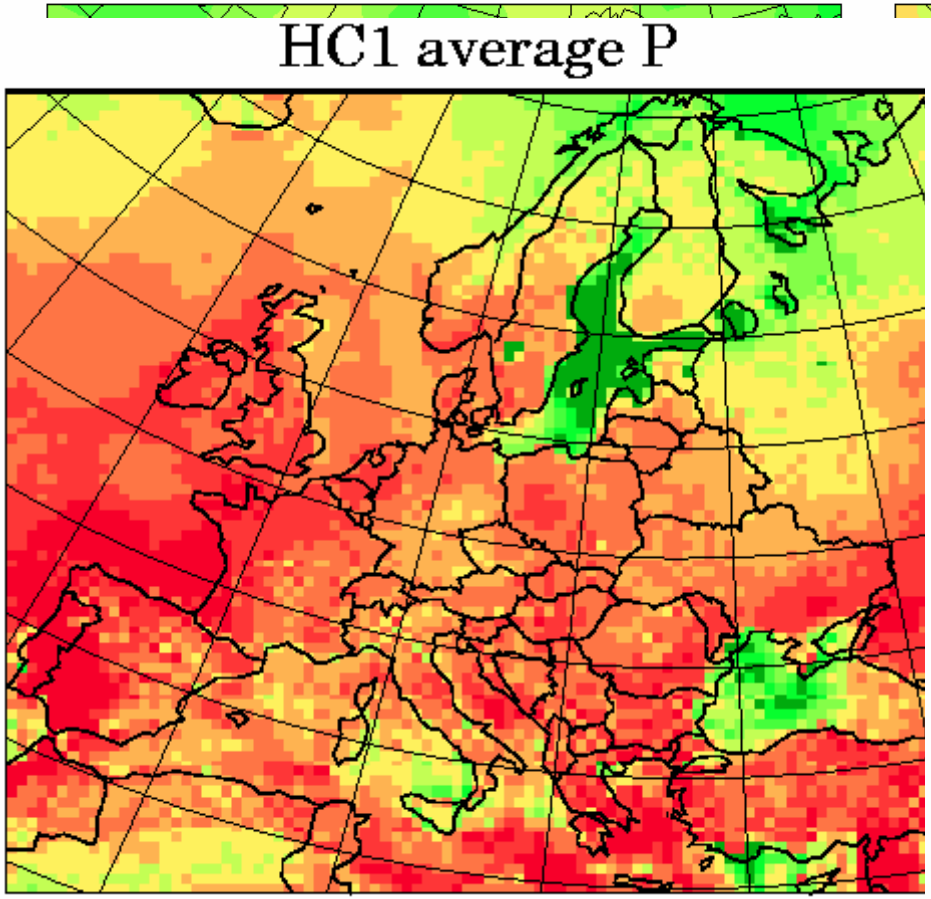
Higher order statistics

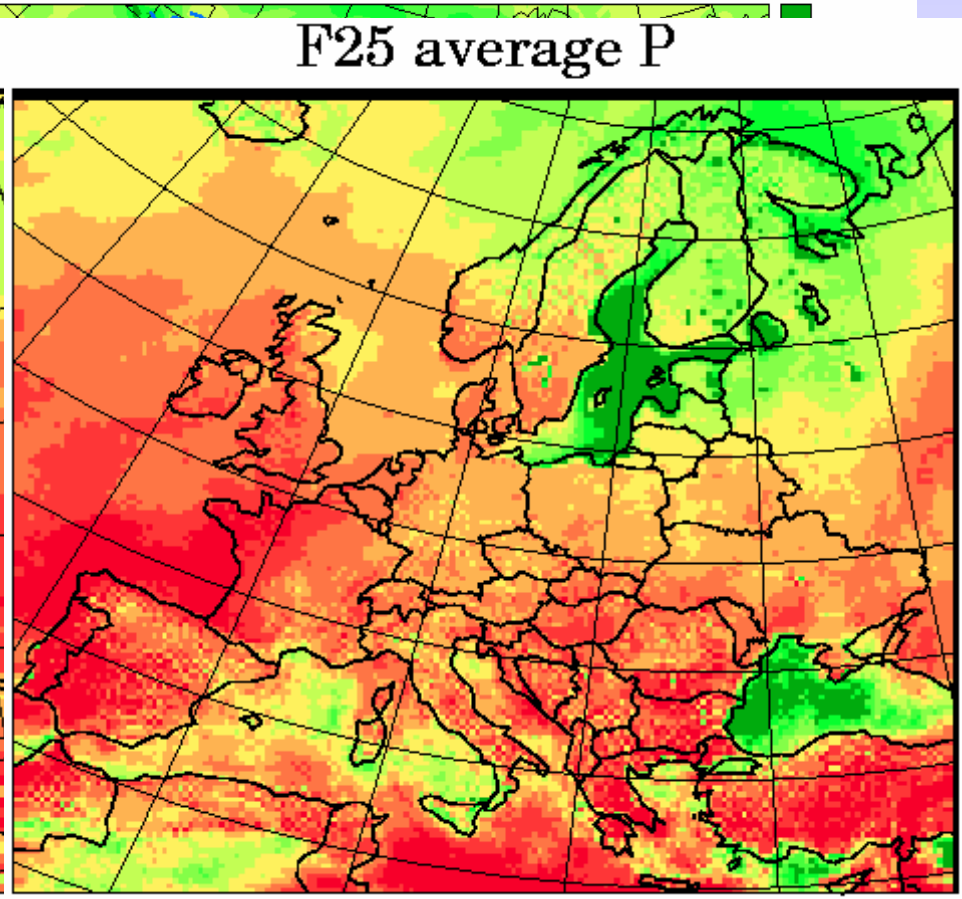
- Droughts
- Flooding

Uncertainty due to GCM and resolution

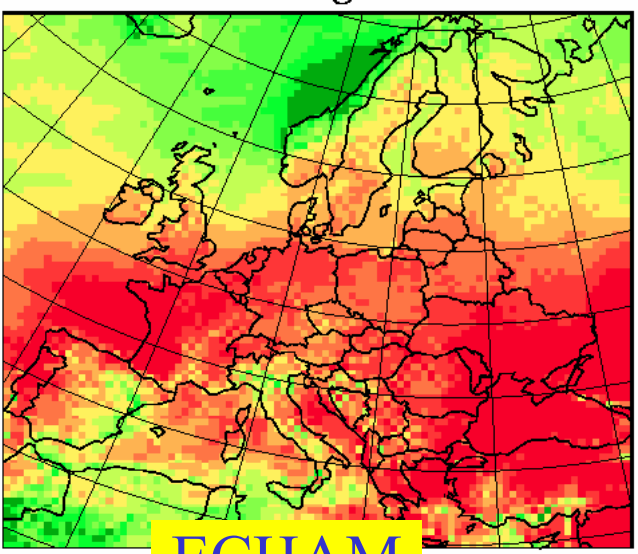
Change in JAS mean precip (2071-2100 minus 1961-1990)

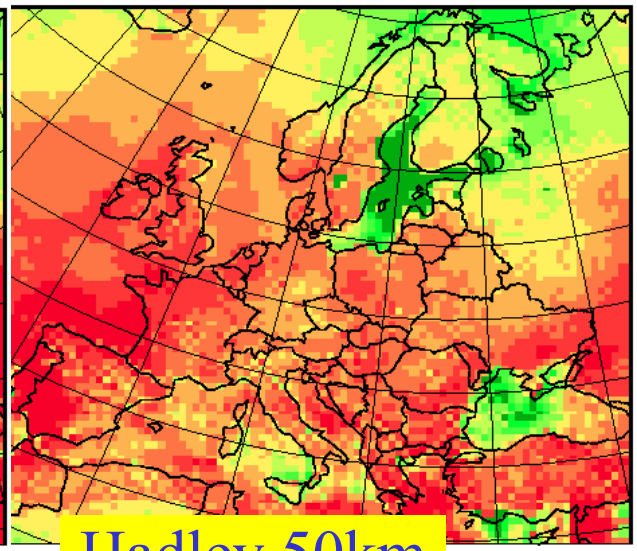
Christensen&Christensen (2004)

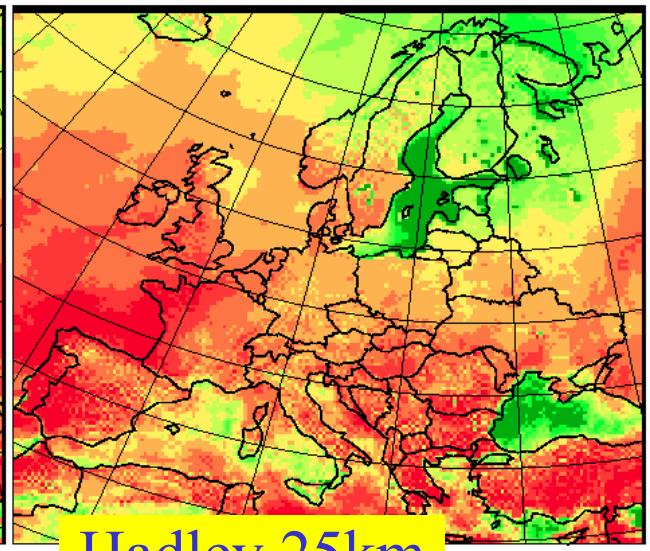




Sensitivity due to GCM and RCM resolution



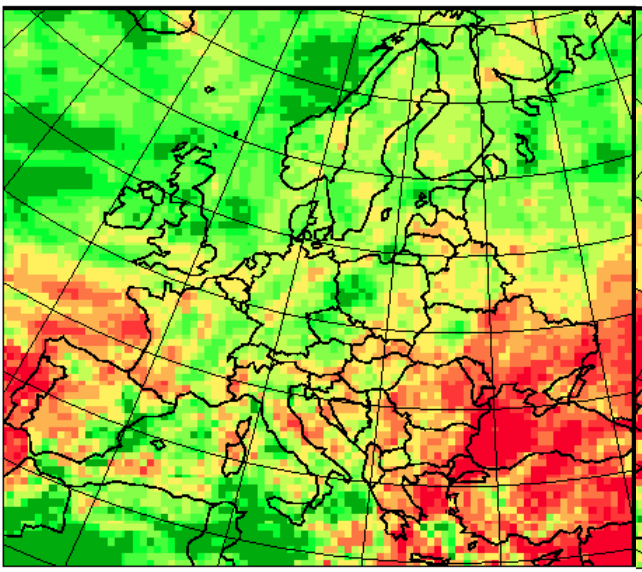


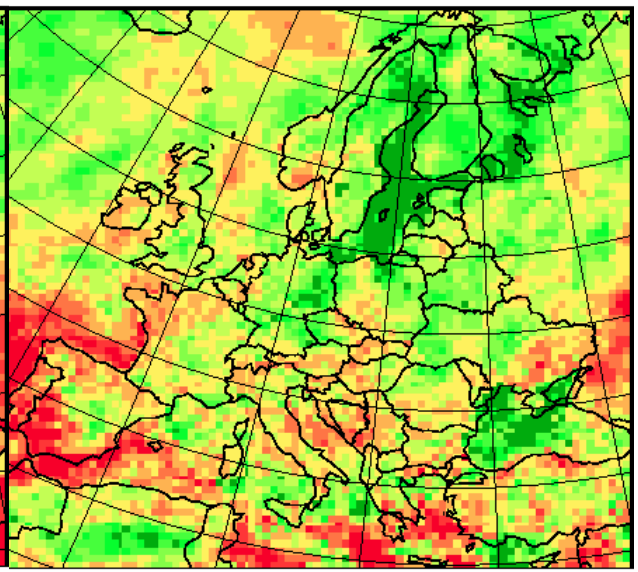


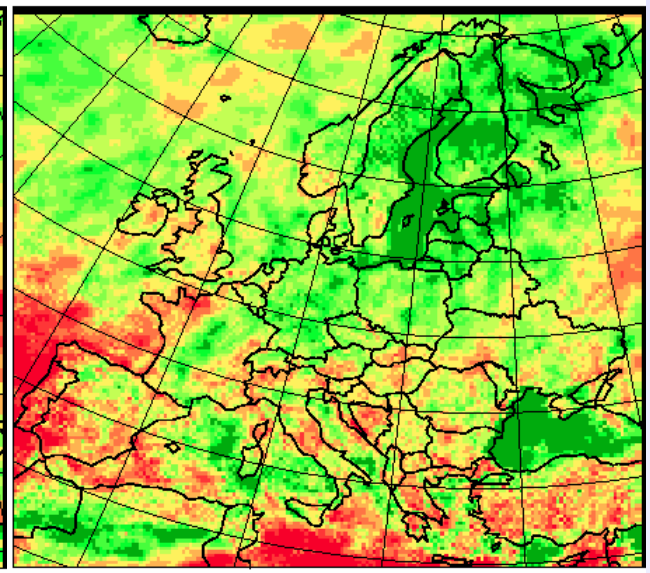
ECHAM

Hadley 50km

Hadley 25km

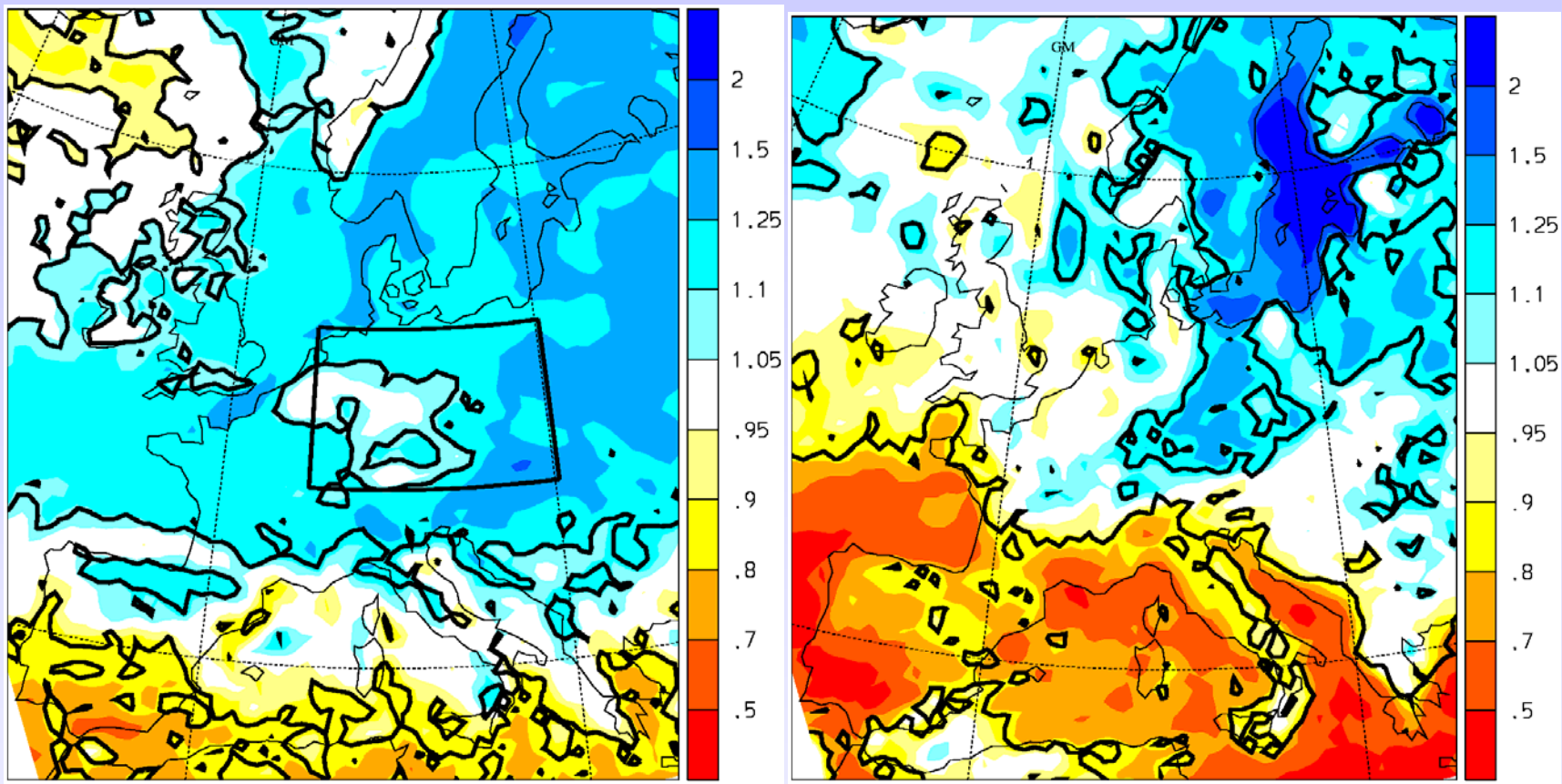






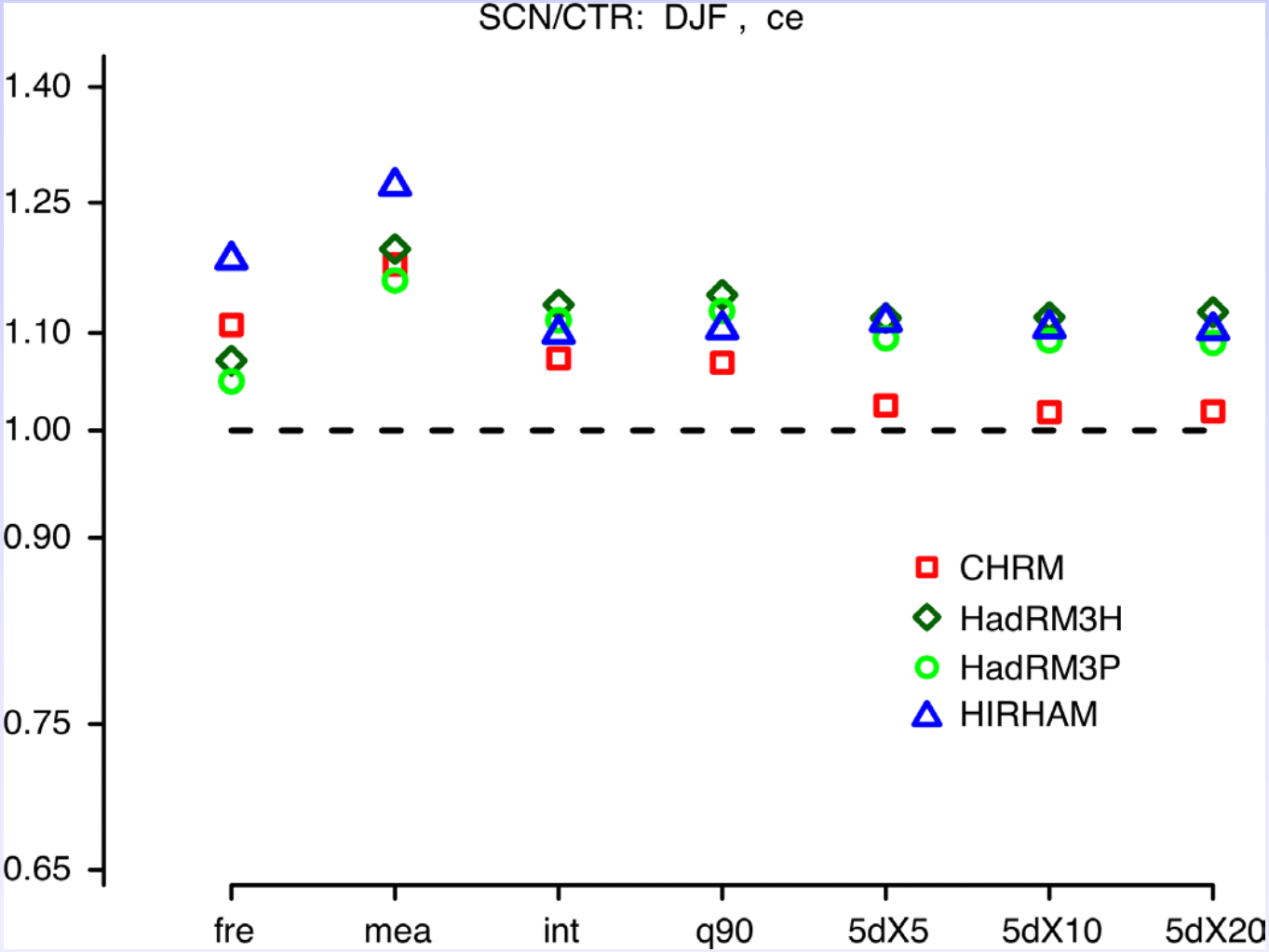
Christensen & Christensen, Nature (2003)

5-year return level of 5-day precip DJF 5-year return level of 1-day precip JJA

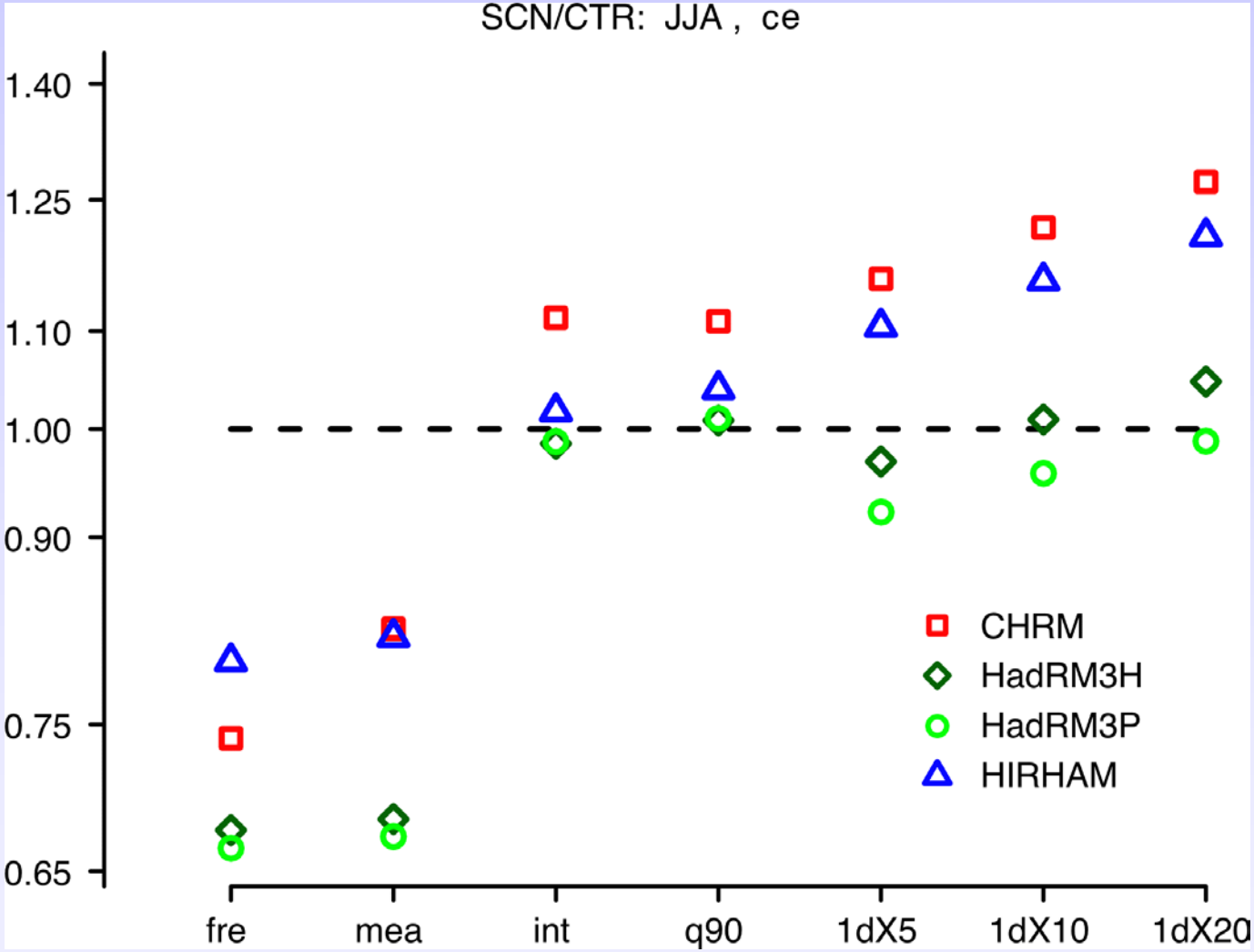


Frei (2004)

Central Europe



Central Europe

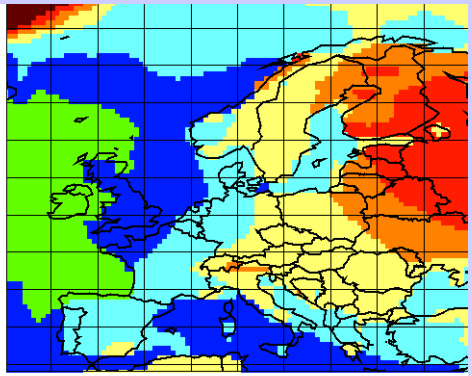


Reproducibility

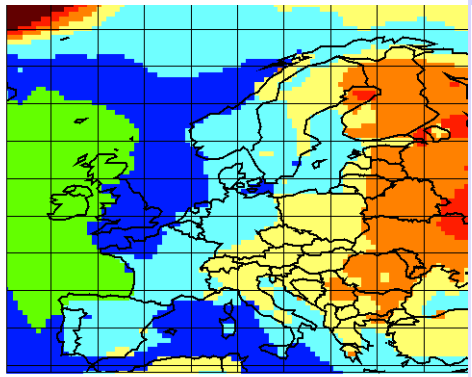
- Assessing uncertainty due to
  - A-GCM formulation
  - RCM formulation

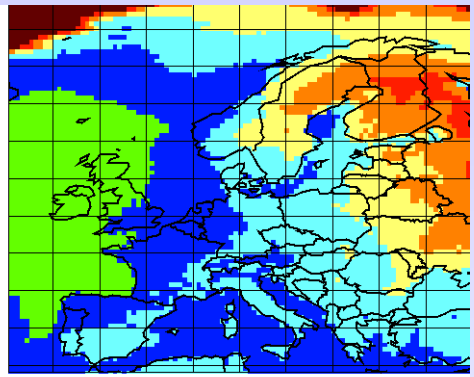
Temperature change DJF

HadAM3P



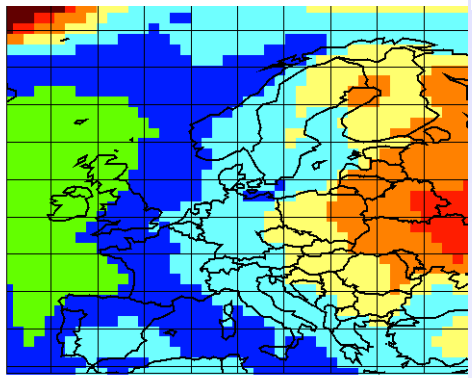
HadAM3H

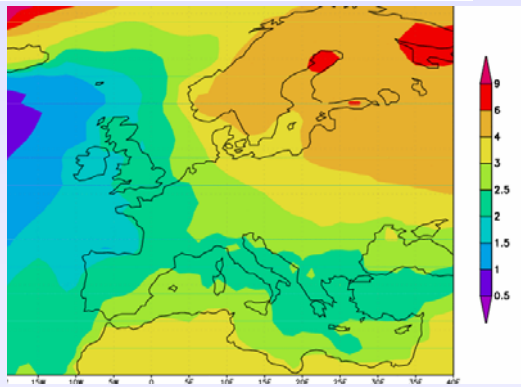




Arpege

ECHAM5





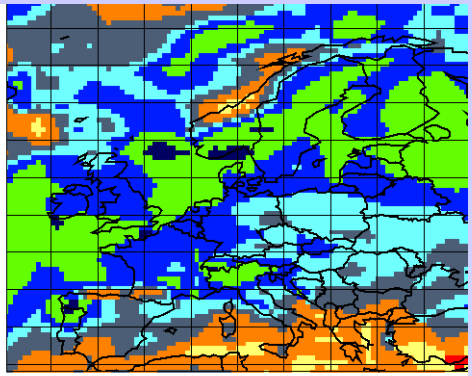
CCM3

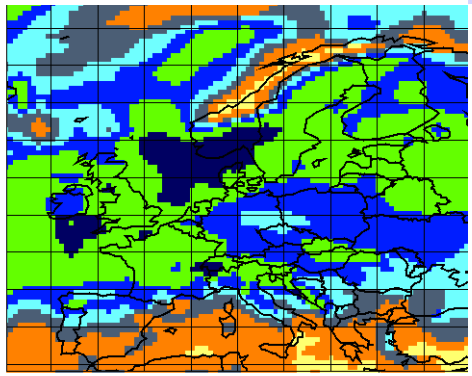
Precipitation change DJF mm/d

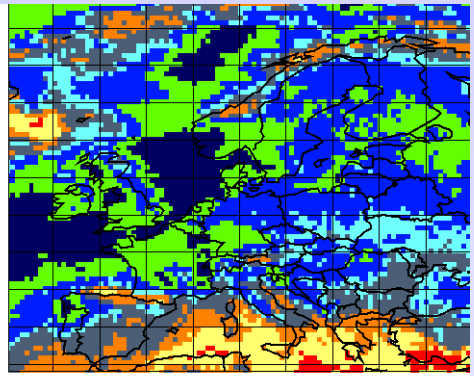
HadAM3P

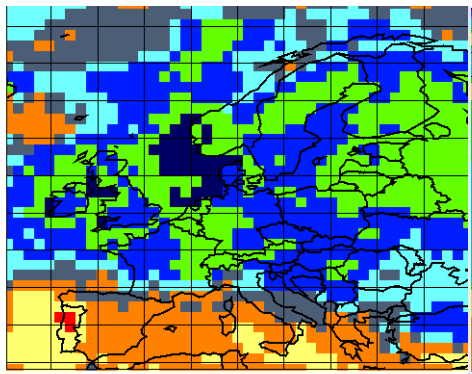
HadAM3H

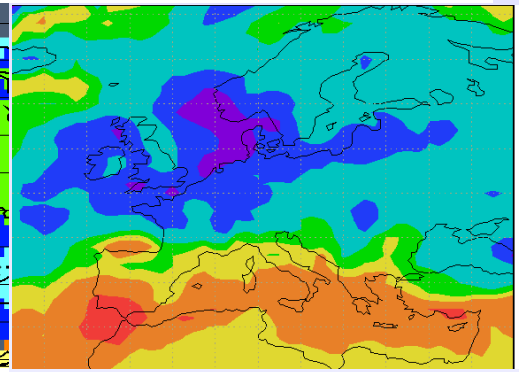
ECHAM5

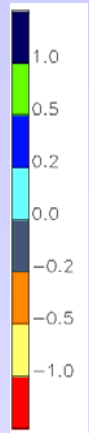




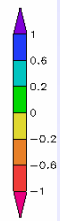








Arpege



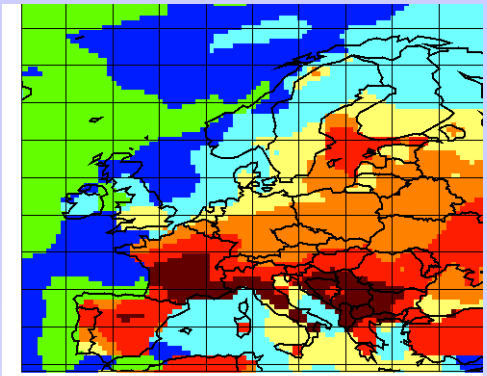
CCM3

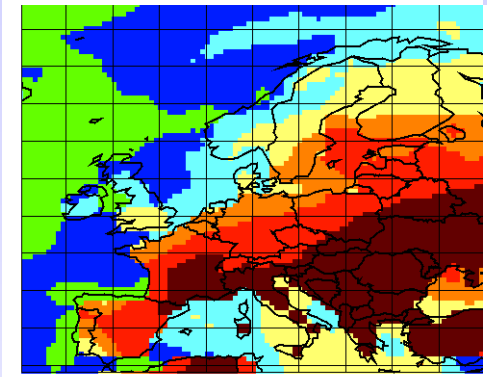
Temperature change JJA

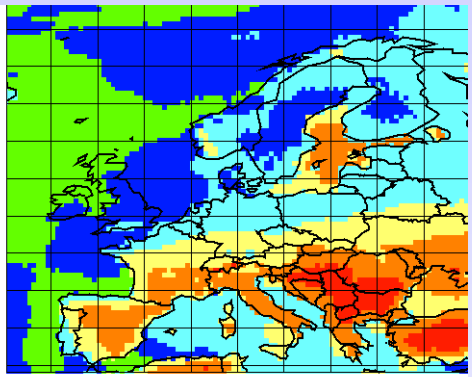
HadAM3P

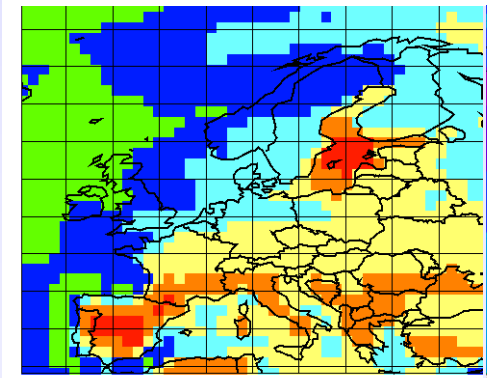
HadAM3H

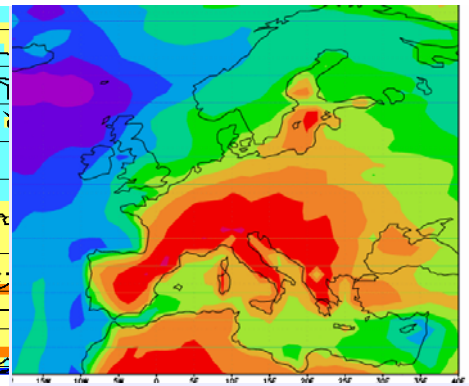
ECHAM5

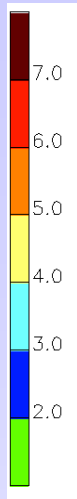












Arpege

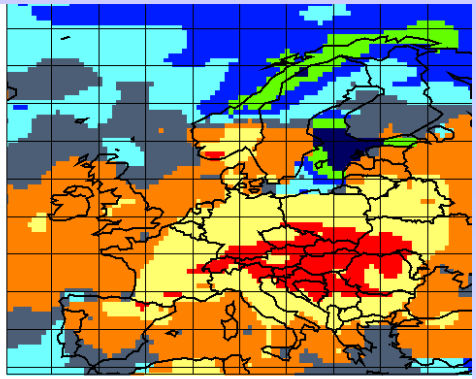
CCM3

PRUDENCE

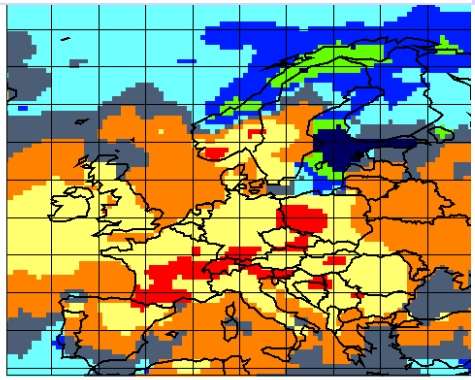
dmi.dk

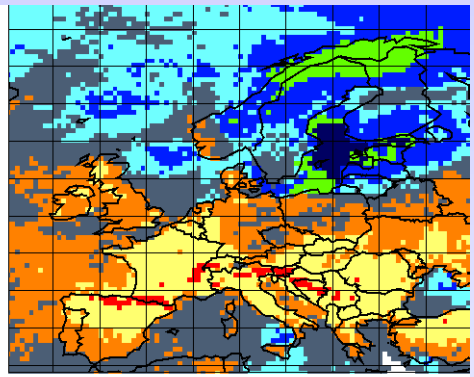
Precipitation change JJA mm/d

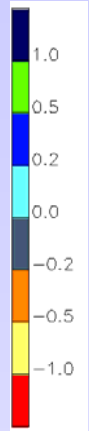
HadAM3P



HadAM3H

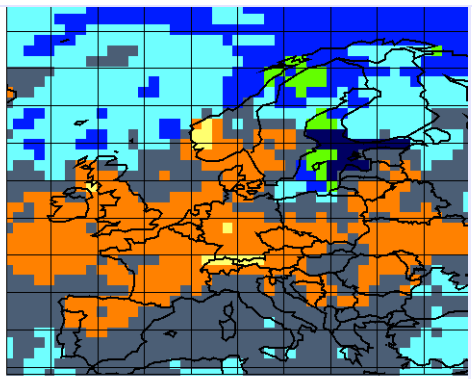


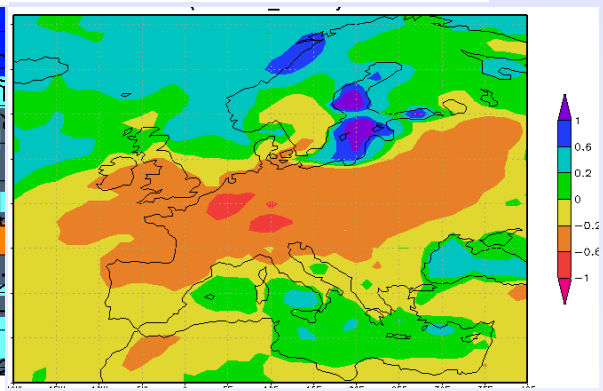




Arpege

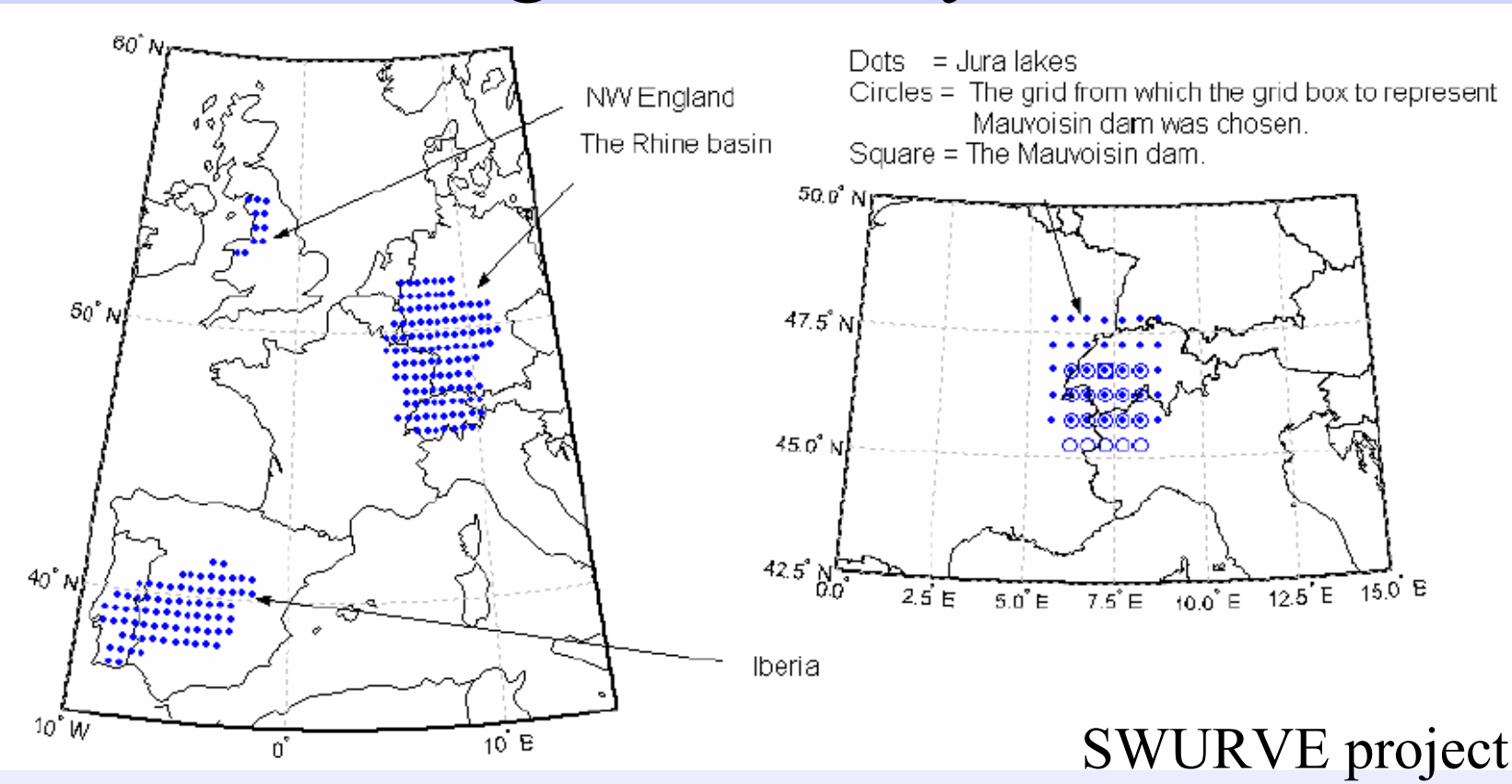
ECHAM5





CCM3

Utilisation of PRUDENCE data for regional analysis



SWURVE project

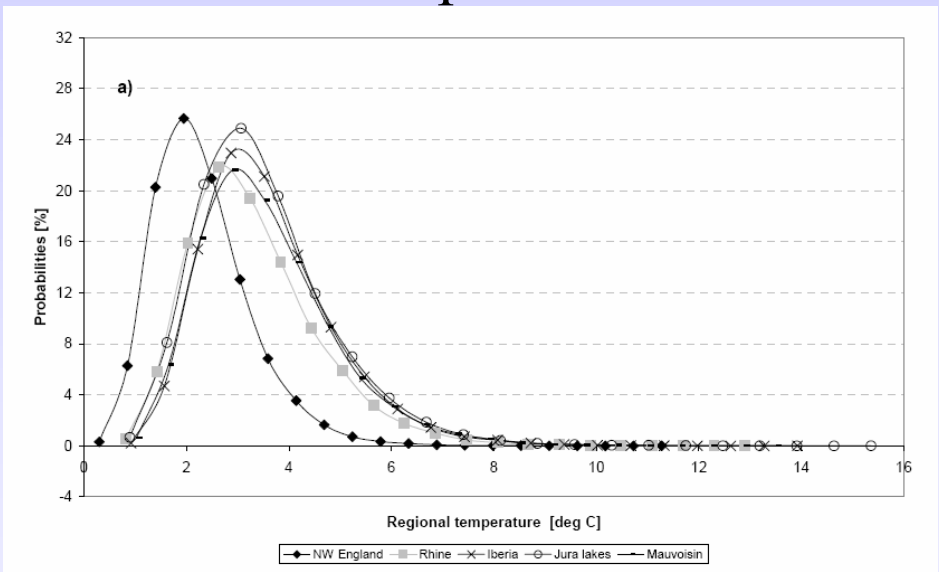
Assessing uncertainty of regional changes

- Combine *PDF* from
  - global annual mean temperature increase
  - Change in regional temperature/precipitation
    - per degree of global temperature increase (Jones, 2000)
- (Uniform distributions from within a range)
- Normal distribution* of *PDF* for the scaling variables, log normal for global increase
- Full range of uncertainty

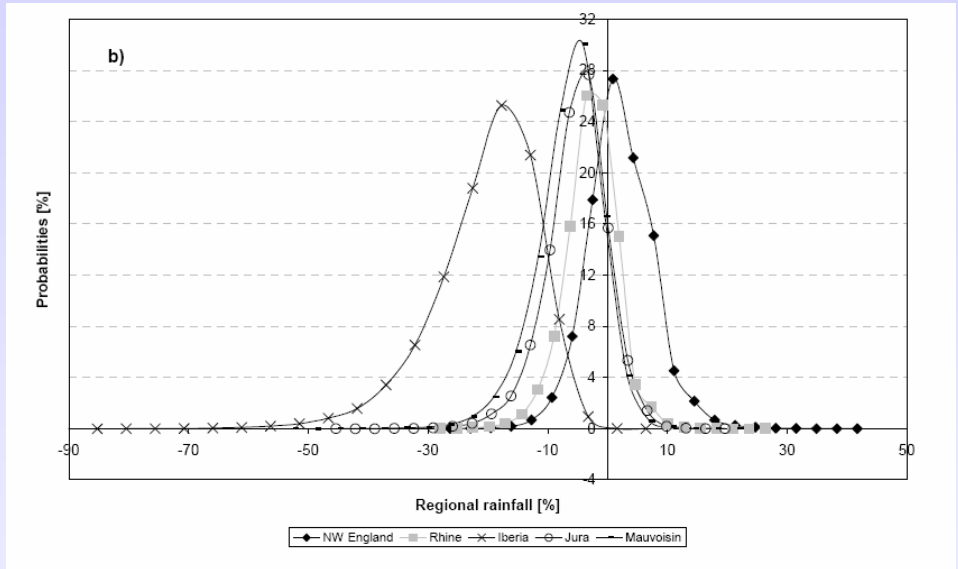
*(estimated from ANalysis Of VAriance (ANOVA))

(2071-2100) wrt. (1961-1990)

Temperature



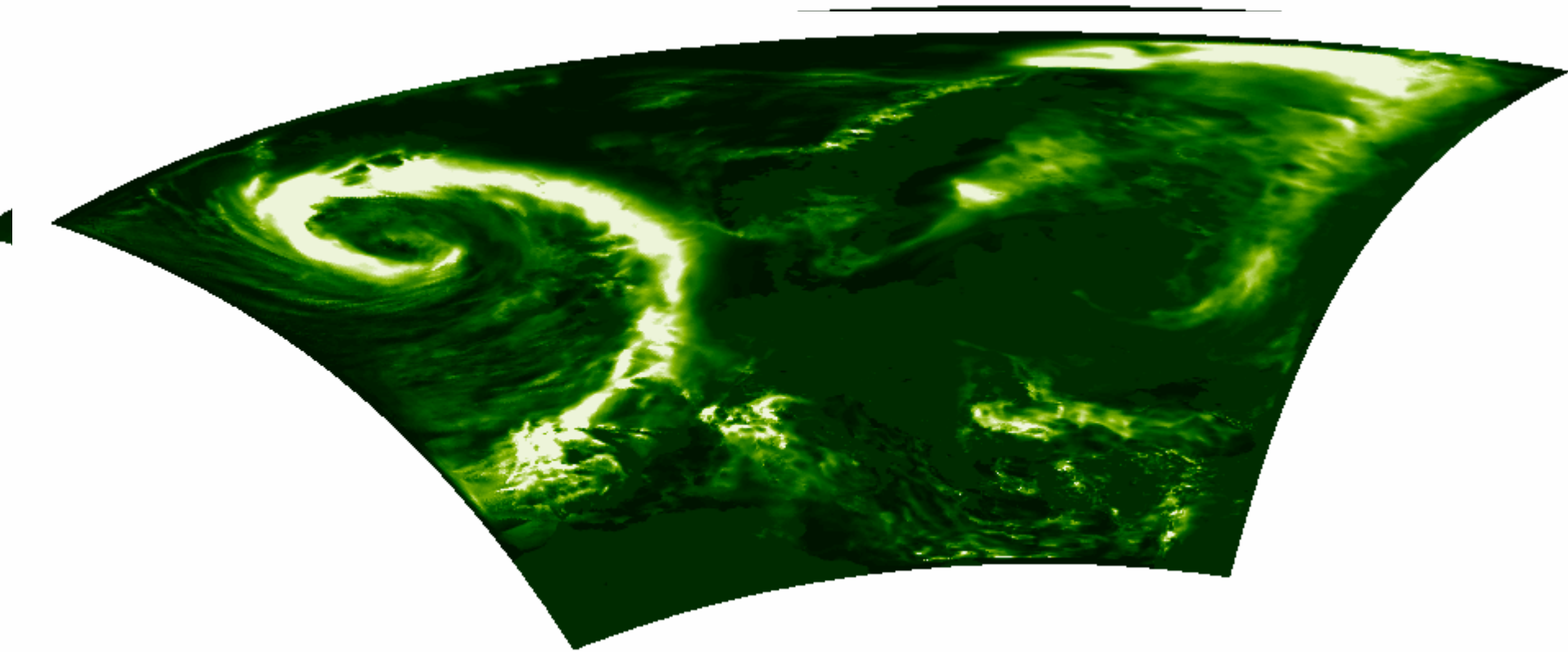
Precipitation



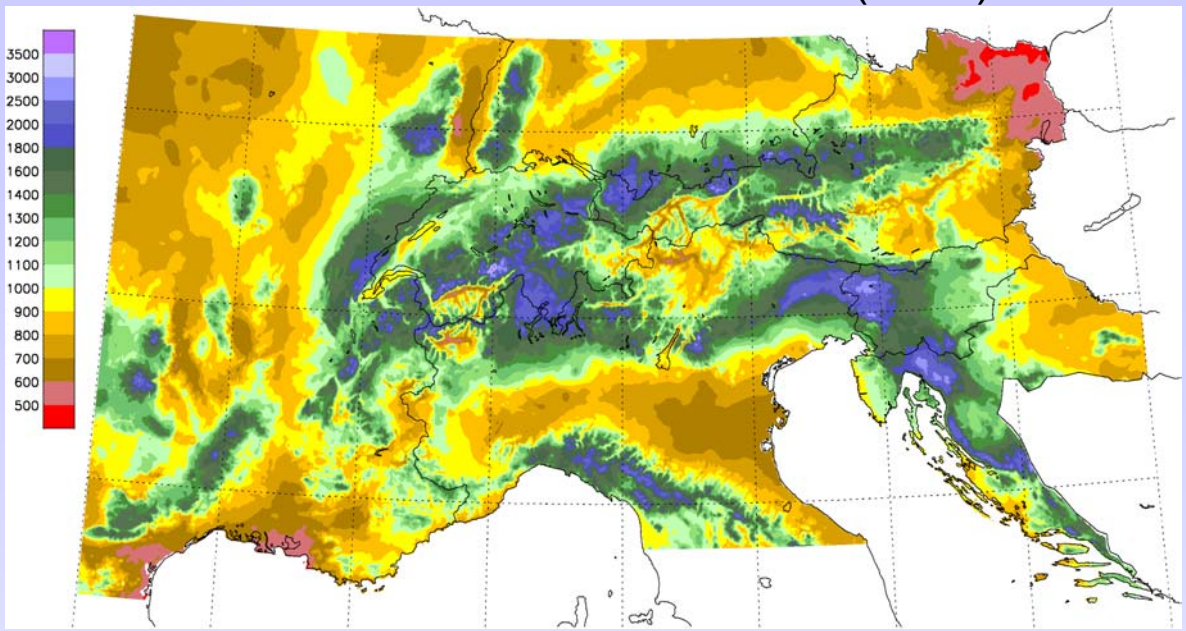
Ekström *et al.* (in submission)

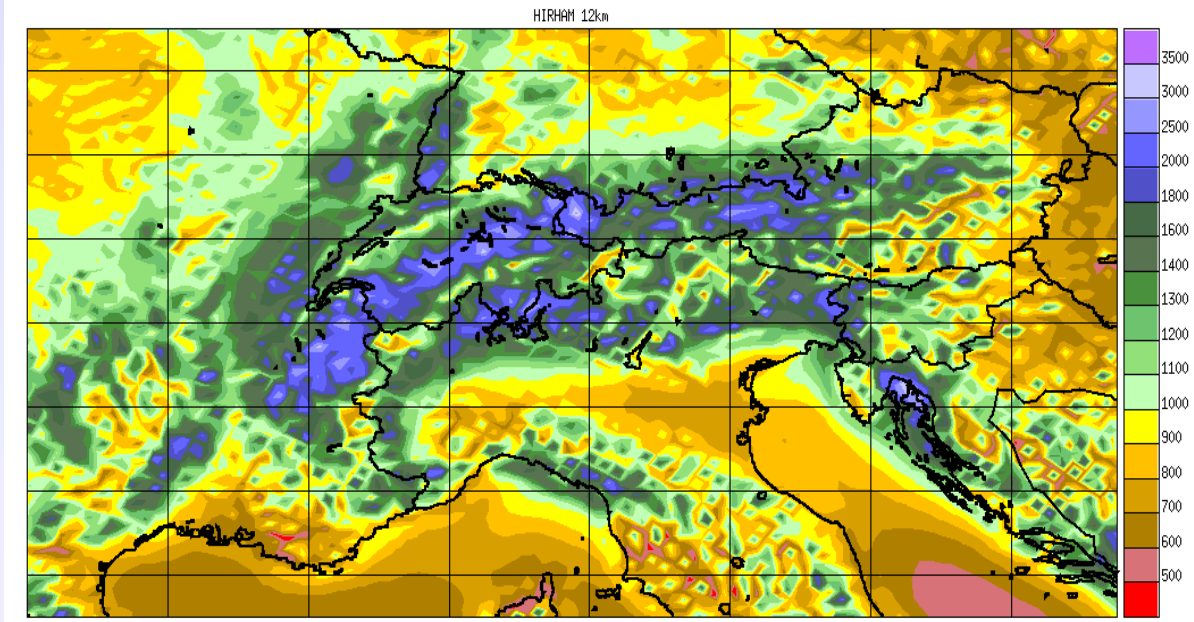
Resolution once more

A snapshot: 17.01.1964



Schwarb and Frei. (2001)





Summary-Conclusions-Outlook

- Uncertainties in climate predictions can be and are currently being addressed using the PRUDENCE data set
- The uncertainty due to A-GCM formulation seem to be of less importance compared to AO-GCM (SST production)
- Uncertainty due to RCM formulation is not negligible when addressing extreme events

Summary-Conclusions-Outlook

- Towards even higher resolution
  - Must identify aspects, where resolution is essential and provides robust results across model formulations etc.
- An RCM is a valuable tool for detailed investigations of climate change
  - Seems to be quite realistic in certain aspects, **but……..**
  - How far can we push them?

Thank you

Recommended list of variables

Daily, monthly and seasonal

- T2m 2-meter temperature (K)
- Precip Precipitation (mm/day)
- Clcov Total cloudiness (Fraction)
- Evap Evaporation (mm/day)
- Snow Snow water equivalent (mm)
- Runoff Total runoff (mm/d)
- Soilw Soil moisture (mm)
- Psurf Surface pressure (hPa)
- MSLP Mean sea level pressure (hPa)
- T2max Daily maximum 2-meter temperature (K)
- T2min Daily minimum 2-meter temperature (K)
- W10m 10-meter wind speed (average length of the wind vector) (m/s)
- W10max 10-meter daily maximum wind speed (m/s)
- Q2 2-meter specific humidity (kg/kg)
- SWnet Net SW radiation (W/m^2) positive
- SWdown Downward SW radiation (W/m^2) positive
- LWnet Net LW radiation (W/m^2) positive
- LWdown Downward LW radiation (W/m^2) positive downward
- Alternatives wrt. moisture:
  - Rh2m 2-meter relative humidity (Fraction)
  - Td2m 2-meter dew point temperature (K)